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A TEST FACILITY FOR THE EVALUATION OF MICROWAVE TRANSMISSION COMPONENTS

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A TEST FACILITY FOR THE EVALUATION OF MICROWAVE TRANSMISSION COMPONENTS

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Abstract

A Low Power Test Facility (LPTF) was developed to evaluate the performance of Electron Cyclotron Resonance Heating (ECRH) microwave transmission components for the Mirror Fusion Test Facility (MFTF-B). The facility generates 26 to 60 GHz in modes of TE$_{01}$, TE$_{02}$ or TE$_{03}$ launched at power levels of 1/2 milliwatt. The propagation of the RF as it radiates from either transmitting or secondary reflecting microwave transmission components is recorded by a discriminating crystal detector mechanically manipulated at constant radius in spherical coordinates. This facility is used to test, calibrate, and verify the design of overmoded, circular waveguide components, quasi-optical reflecting elements before high power use.

The test facility consists of microwave sources and metering components, such as VSWR, power and frequency meters, a rectangular TE$_{10}$ to circular TE$_{01}$ mode transducer, mode filter, circular TE$_{01}$ to 2.5 inch diameter overmoded waveguide with mode converters for combinations of TE$_{01}$ to TE$_{03}$ modes. This assembly then connects to a circular waveguide launcher or the waveguide component under test. RF output from the launcher is monitored by a rectangular waveguide and detector mounted on a mechanical arm. The arm is articulated by computer controlled stepper motors to operate in spherical coordinates at a preset constant radius from an RF output workpoint. Position-monitoring is reported by stepper motor controllers interfacing with a LSI-11 series computer with a Winchester hard disk drive as a data storage media. Output is plotted in real-time on a cartesian-recorder and also transferred to the Magnetic Fusion Energy Computer Center User Service Center Dec 10 for further data reduction and graphical manipulation.

Results to date consist of design verification and calibration of all ECRH MFTF-B Waveguide components with great success. Work planned will consist of the testing of holographic microwave devices for quasi-optical transmission systems. System design and results will be presented.

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Introduction

This test facility was built to support development of the ECRH microwave transmission components. These components will be installed in and on the MFTF-B vacuum vessel and transmit polarized, phase-corrected microwaves to the anchor regions by quasi-optical transmission techniques [1]. Microwave heating in the anchor regions is required for the formation of thermal barriers which will allow plug densities to be maintained lower than the central cell density, thus reducing end-plug power consumption and magnetic field requirements [2]. The LPTF is used as a diagnostic in the design, calibration and design confirmation of all ECRH waveguide and quasi-optical Holographic Microwave Elements (HOME) [3]. Over seventy individual microwave components have and will be evaluated in this facility. Consequently, the LPTF was designed for relative ease in reconfiguration for various test schemes, automatic data gathering, as well as optimized data reduction and presentation. The result is a versatile facility that is capable of fullfilling the needs for microwave low power cold testing for a variety of applications.

Design

The design for the LPTF was based on data aquisition taken in a spherical coordinate system as shown in Fig. 1. Such a design allows for the evaluation of radiation patterns without the need for cumbersome data manipulation. This also allows detailed mapping of specific areas of interest after an entire hemispherical pattern has been mapped. Moreover, the identity of predominant TE and TM modes is pronounced.

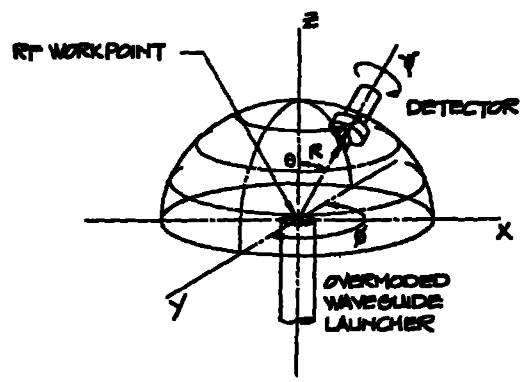

Figure 1. The LPTF coordinate system.

A detector is suspended and manipulated at constant radius from the evaluated component with a positional accuracy of ± 0.1 cm at a mapping radius R, of 40 cm. R can be adjusted over a range from 5 to 300 cm. The mapping range is from 0 to 90 degrees for theta and 0 to 360 degrees for phi. The RF sources currently available are varaible from 26 to 60 GHz at 0 dBm for TE$_{01}$, TE$_{02}$, or TE$_{03}$ modes for 6.35 cm diameter circular waveguide, corresponding to the predominant primary and secondary harmonic frequencies required for the eight channels for ECRH on MFTF-B [2]. Data acquisition and manipulation of the detector head is accomplished by a DEC LSI-11 computer and stepper motor controllers. A menu-driven system allows variation of field mapping parameters. Once initialized, the system traverses the field, records and reduces data, as well as de-initializing itself to the original start position. The overall system architecture is depicted in Fig. 2.

RF Source and Signal Conditioning Subsystems

The primary RF signal source is a Hewlett-Packard (HP) 8350B sweep oscillator mainframe. Various microwave frequency bands are available by using different RF plug-in units compatible with the HP sweep oscillator. 26.5 GHz to 40 GHz is obtained by using an 83572B plug-in unit while 18 GHz to 26.5 GHz is obtained from a 8370A plug-in unit. To obtain 56 GHz (one of the

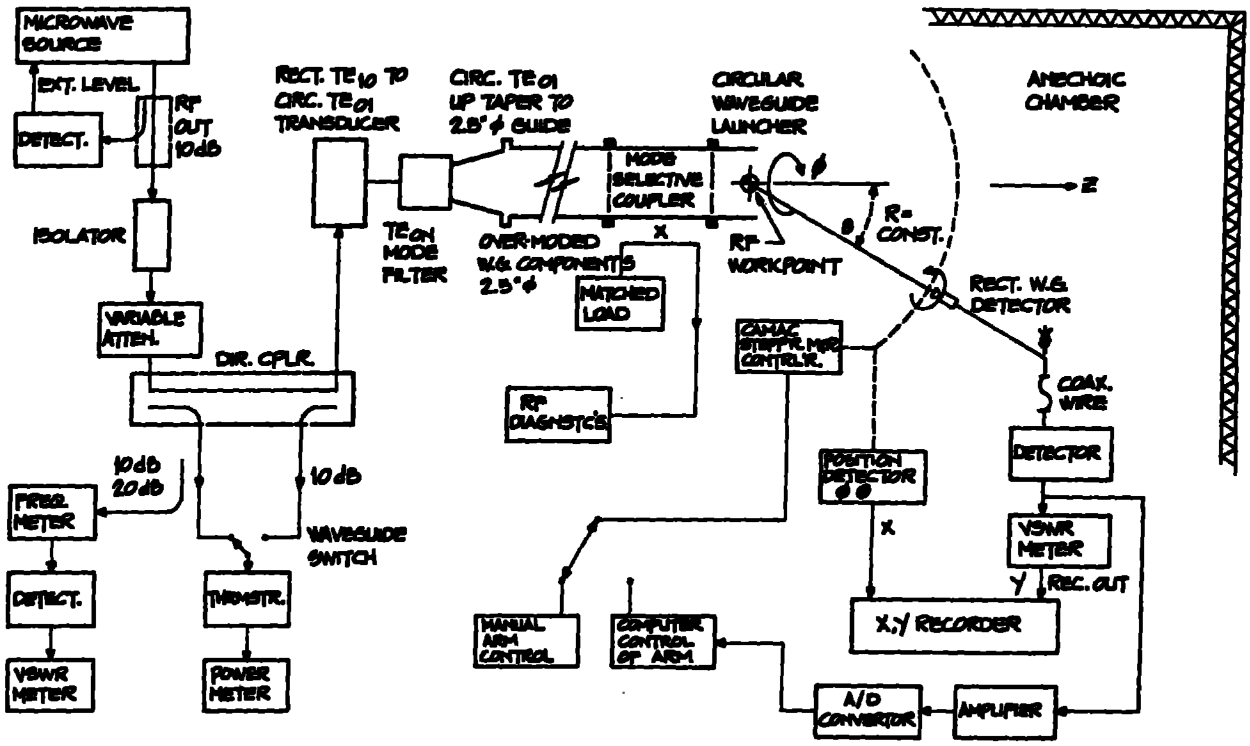

Figure 2. The LPTF architecture for the testing of overmoded waveguide components.

three ECRH operating frequencies), a Watkins-Johnson (WJ) model WJ-1204-41 frequency tripler is used in conjunction with the 83570A plug-in unit. The sweep oscillator outputs are externally leveled to provide a stable RF power level. The ferrite isolator is used to provide protection of the source from excessive reflected power, and TE_{10} directional couplers are used to monitor forward and reflected power in the rectangular waveguide system. The RF power is then converted from a TE_{10} mode in rectangular waveguide to a TE_{01} mode in circular waveguide by using a Lanciani transducer and TE_{0n} mode filter [4]. The RF output of the specific source goes through a variety of TE_{10} rectangular waveguide components. The TE_{0n} is used to attenuate spurious nonsymmetric modes such as TE_{21} which is the predominant spurious mode produced by the transducer. The TE_{01} output of the mode filter for the specific operating frequency is applied to a z-section TE_{01} conical taper which is used to excite the TE_{01} mode in 6.35 cm diameter waveguide [5]. The main spurious modal output of the taper is TE_{02}, which is at a level of 30 dB below the predominant TE_{01} mode. TE_{02} and TE_{03} modes are generated by using sets of periodic radial wall perturbation mode converters [6]. The waveguide component being tested is inserted between the TE_{01} taper or the appropriate set of mode converters and the waveguide launcher to determine the modal propagation properties of the component being tested.

Articulated Arm and Facility

The requirement for a mechanically manipulated detector holder operating in a spherical coordinate system with constant radius yielded a design as shown in Fig. 3. A boom holds the detector at the fixed radius. A parallel linkage system maintains the detector at a true radial attitude relative to the RF work point throughout its entire traverse range. The detector can rotate about its axis indexed by a counterweight for field mapping extraneous of polarization, or can be fixed in place allowing specific polarization. A stepper motor drives a worm and ring gear arrangement for movement through theta. Rotational movement through phi is accomplished by another worm/ring gear arrangement also rotating the theta drive. Backlash in the gear drive is minimized by a preload adjustment. A bearing housing and support bracket comprise the foundation for both the phi and theta drives. The large bearing housing allows the passage of waveguide components up to 13 cm in diameter. To test an overmoded waveguide component, a waveguide extension is passed through the bearing housing bore terminating at the constant radius workpoint. The workpoint was placed sufficiently forward to alleviate the possibility of random RF reflections from the bearing housing. Adjustment to a different radius is accomplished by relocating the detector compensating linkage along the boom. The entire mechanism is mounted on an optical test bench to provide a sufficient anti-vibrational mass.

The materials of construction consisted of various alloys for components sufficiently behind the RF constant radius workpoint. Components adjacent to and forward of the workpoint were fabricated from non-RF reflecting materials such as epoxy-fiberglass and graphite-fiberglass composites for the boom, compensation linkage, and detector holder. In the latter, graphite composites were selected for the boom and compensation linkage principally for their excellent structural properties. The cantalevered mass is substantially reduced, thus decreasing total deflection, particularly at far field distances approaching 3 meters. Construction was by lamination of a biased weave on a foam core. In certain areas, spruce was also bonded to the foam core. Machining of these components was then done on traditional machine shop equipment. Bearing components were fabricated from polymers with high lubricity. Assembly and setup was accomplished with basic jig tools. Figure 4 shows the completed articulated arm with the radius adjusted for near-field measurements.

Control and Data Acquisition

The test facility is controlled by CAMAC hardware interfaced to a DEC LSI-11 computer system, consisting of A floppy/Winchester disk drive, printer, LLNL-designed serial highway transmitter/receiver, and 1200-baud modem. S & H Computing TSX-Plus operating system is used, and all software is written in Pascal. The phi and theta drive motors are operated by a Kinetic Systems 3361 stepping motor controller, and RF amplitude data is digitized by a 3553 A/D converter.

The facility control program is menu driven and allows a number of test functions, such as direct CAMAC access and drive scanning, as well as the ability to record a data scan. To record a data scan, the operator must enter a file name, three lines of comments, and phi and theta parameters in degrees. The scan is then completely automatic. The operator-entered data indicated above is written into an ASCII file, and the recorded data is then written in a minimum length integer format to save file space. Each line of data uses 11 characters and is comprised of the phi scan number, theta data point number, and

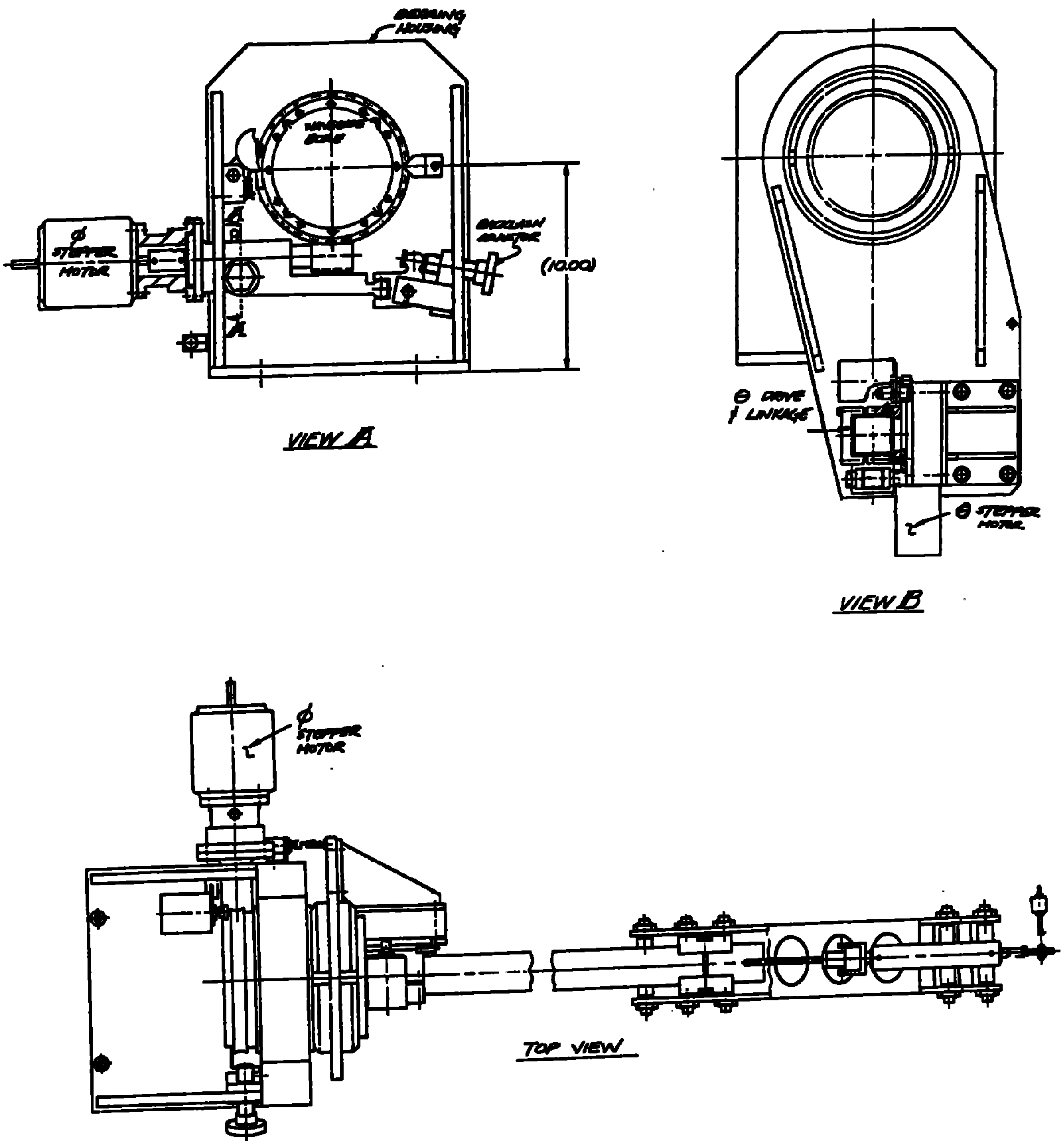

Figure 3. Articulated arm assembly.

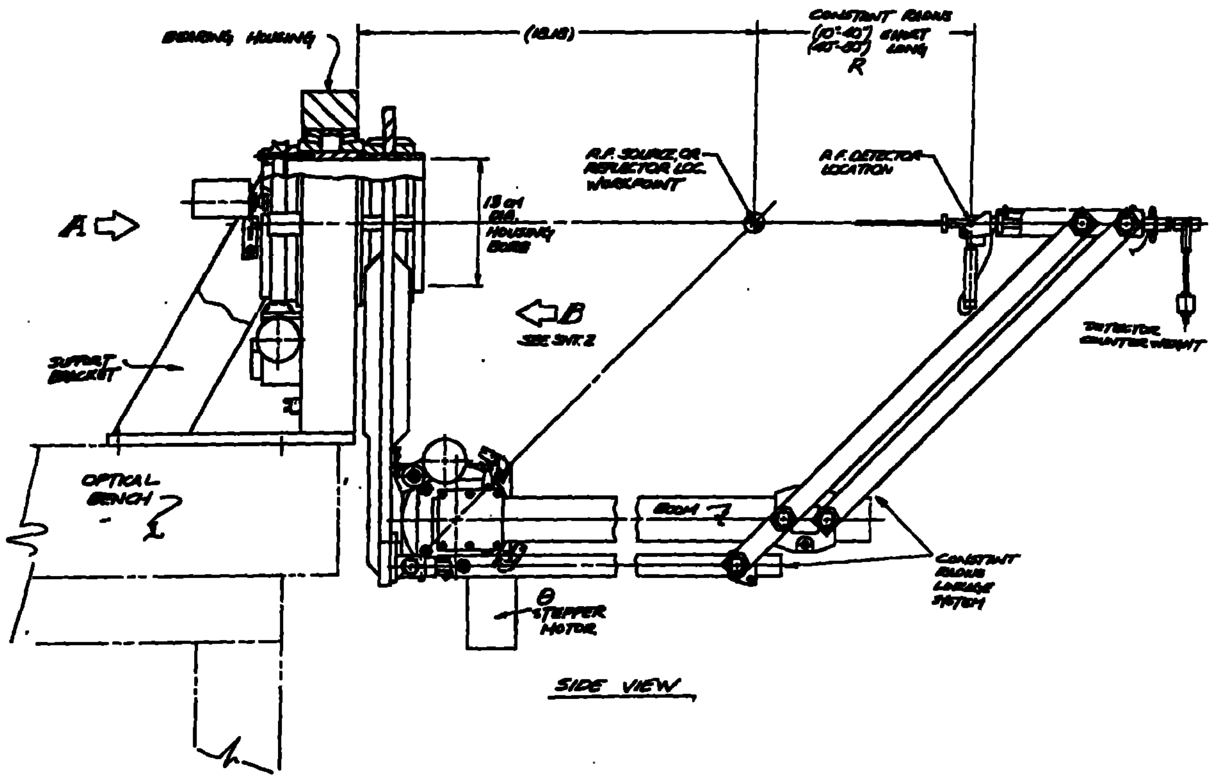

Figure 3. Articulated arm assembly (continued).

Figure 4. The articulated arm adjusted for near-field measurements. Anechoic chamber surrounds equipment.

the data. Using the scan limits and deltas, recorded at the beginning of the file, the plotting program described in the next paragraph calculates the real numbers in degrees.

The data file is transmitted to a DEC PDP-10 system, located in another building, via the modem and phone lines. Kermit, an error-checking terminal emulator program, is used to effect the transfer.

The PDP-10 system is used for the plots because of the availability of the necessary plotting hardware and software. The plotting program interfaces to GRAFL. GRAFL is a program which drives GRAFLIB to easily produce hardcopy plots. RF amplitude data is normalized and plotted vs position in degrees for each phi position. To better interpret the data, both linear and log amplitude are output. Each plot is fully labeled, and the three lines of comment information is included to help eliminate confusion.

Typical 28 GHz patterns are shown in Figs. 5 and 6 for a 28 GHz TE_{01} taper and 28 GHz TE_{02} mode converters, respectively. A variety of 28 GHz waveguide components such as directional couplers, corrugated waveguide, mode filters, and dc blocks have been successfully evaluated using this facility [7].

References

[1] Krause, K. H., "MFTF-B ECRH System Construction Progress and Preliminary Test Results," Proc. 10th Symp. on Eng. Prob. of Fusion Research, IEEE Publ. (1983).

[2] Krause, K. H., G. G. Pollock, J. J. Yugo, "The MFTF-B Electron Cyclotron Resonance Heating System," Proc. 9th Symp. on Eng. Prob. of Fusion Research, IEEE Publ. (1981).

[3] Yugo, J. J., J. W. Shearer, and R. W. Ziolkowski, "MFTF-B Quasi-Optical ECRH Transmission System," American Physical Society (1983).

[4] D. A. Lanciani, "H_{01} Mode Circular Waveguide Components," presented at the Conference on Millimeter Wave Research and Applications, Washington D.C., pp. 45-51, October 15, 1953.

[5] L. Solymar, "Design of a Two-Section Conical Taper in Circular Waveguide System Supporting the H_{01} Mode," The Proceedings of the Institution of Electrical Engineers, Vol. 106, part B supplement, No. 13, pp. 119-120, January 1959.

[7] Poole, B. R. and C. G. Fong, "Design of Mode-Selective Directional Couplers for ECRH on MFTF-B," 11th Symposium, 1985.

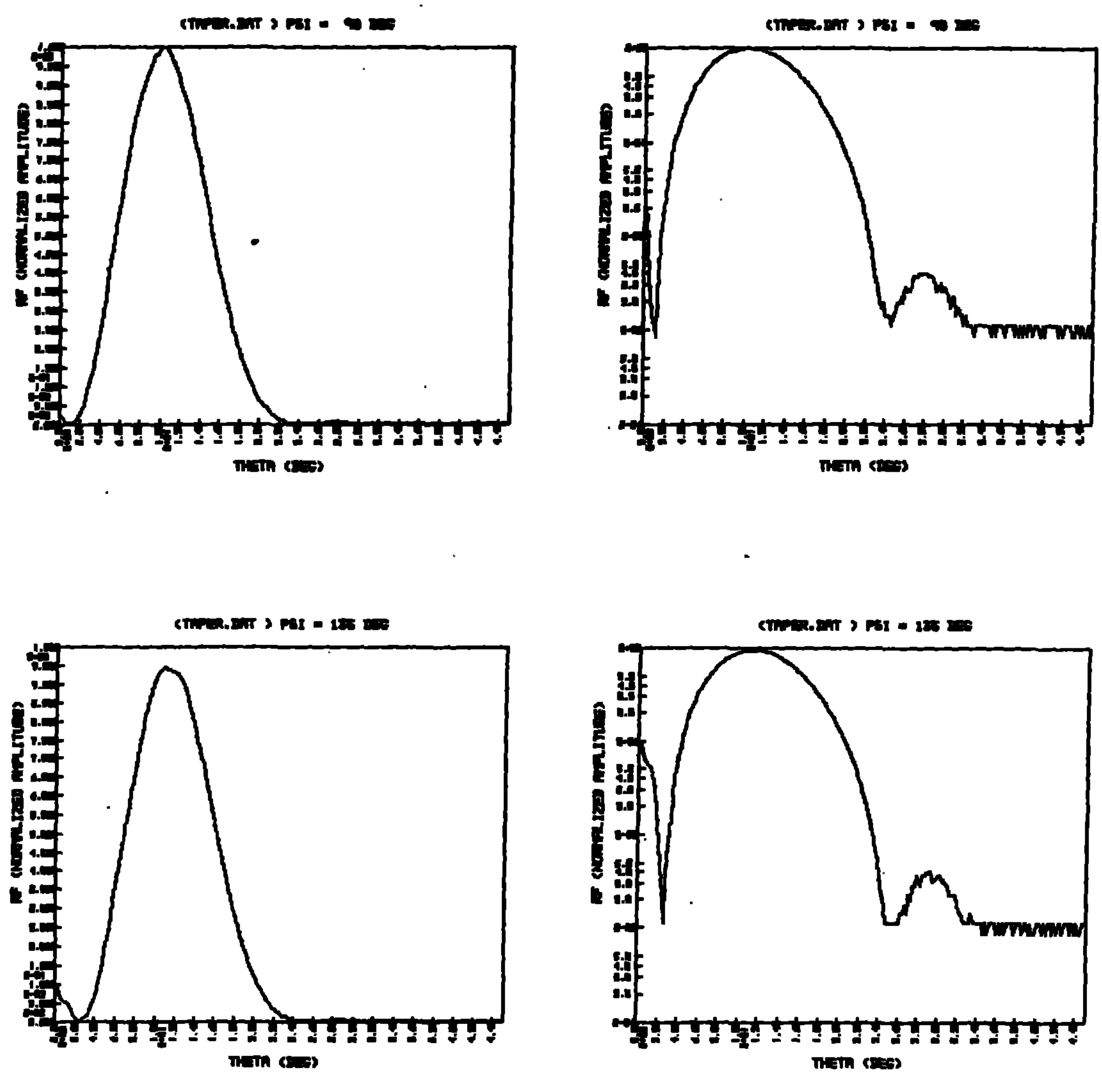

Figure 5. 28 GHz TE_{01} taper output.

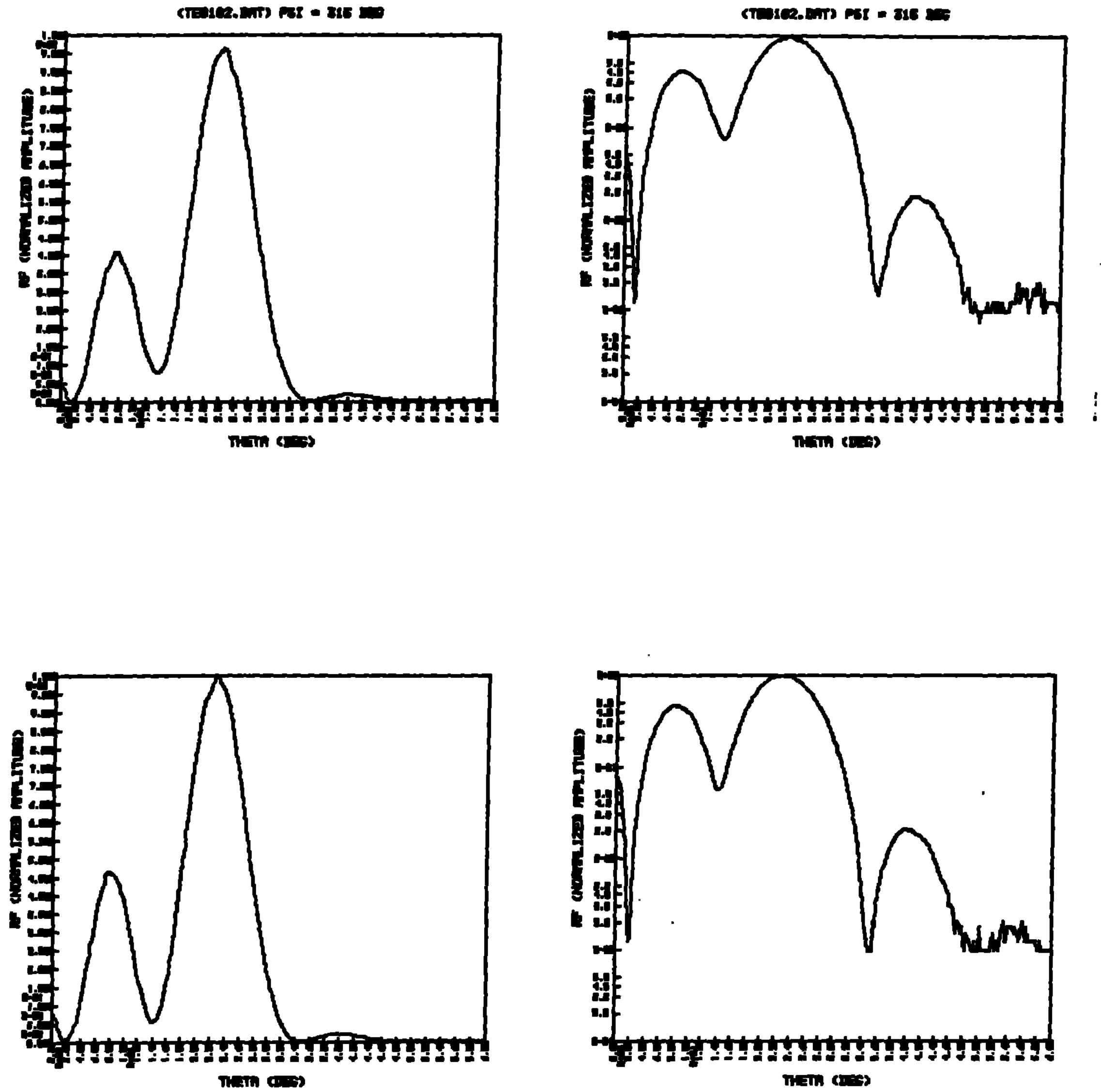

Figure 6. 28 GHz TE_{01}-TE_{02} mode converter output.